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Advanced Technology Vehicle Testing

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ADVANCED TECHNOLOGY VEHICLE TESTING

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Abstract

The light-duty vehicle transportation sector in the United States depends heavily on imported petroleum as a transportation fuel. The Department of Energy's Advanced Vehicle Testing Activity (AVTA) is testing advanced technology vehicles to help reduce this dependency, which would contribute to the economic stability and homeland security of the United States. These advanced technology test vehicles include internal combustion engine vehicles operating on 100% hydrogen (H2) and H2CNG (compressed natural gas) blended fuels, hybrid electric vehicles, neighborhood electric vehicles, urban electric vehicles, and electric ground support vehicles.

The AVTA tests and evaluates these vehicles with closed track and dynamometer testing methods (baseline performance testing) and accelerated reliability testing methods (accumulating life-cycle vehicle miles and operational knowledge within 1 to 1.5 years), and in normal fleet environments.

The Arizona Public Service Alternative Fuel Pilot Plant and H2-fueled vehicles are demonstrating the feasibility of using H2 as a transportation fuel. Hybrid, neighborhood, and urban electric test vehicles are demonstrating successful applications of electric drive vehicles in various fleet missions. The AVTA is also developing electric ground support equipment (GSE) test procedures, and GSE testing will start during the fall of 2003. All of these activities are intended to support U.S. energy independence. The Idaho National Engineering and Environmental Laboratory manages these activities for the AVTA.

Keywords: Hydrogen, Electric Vehicle, HEV (hybrid electric vehicle), IC Engine (ICE), NEV (neighborhood EV).

1. Introduction

Given the United States' heavy dependence on imported petroleum as a transportation fuel and the turmoil in many of the regions providing imported petroleum, using domestic energy sources for transportation is increasingly important to the energy independence (and homeland security and economic stability) of the United States. The goal of attaining energy independence is supported by efforts to develop advanced technology vehicles powered by domestic energy sources such as hydrogen and electricity.

In addition to reducing the use of petroleum, using H2 as a fuel in advanced-technology internal combustion engine (ICE) vehicles provides significant air emissions benefits. Testing H2 ICE vehicles also supports development of the H2 infrastructure needed for fuel cell vehicles. Other advanced technology test vehicles include urban electric (UEV), hybrid electric (HEV), and neighborhood electric (NEV) vehicles. While HEVs that maximize petroleum use are increasingly being offered by original equipment manufacturers, surveys suggest the public needs additional information about them.

The U.S. Department of Energy's Advanced Vehicle Testing Activity (AVTA) is evaluating many of these advanced technology vehicles in closed-track and dynamometer environments (baseline performance testing), as well as in real-world applications, including fleet testing, accelerated reliability testing (accumulating life-cycle vehicle mile and operational knowledge within 1 to 1.5 years), and public demonstrations.

The objective of the AVTA is to increase the body of knowledge as well as the awareness and acceptance of electric drive and other advanced technology vehicles. This enables the AVTA to provide fleet managers, the general public, and other potential advanced technology vehicle users with accurate and unbiased information on vehicle performance and infrastructure needs, so they can make informed decisions about acquiring and operating advanced technology vehicles.

The Idaho National Engineering and Environmental Laboratory manages these activities.

2. Hydrogen Testing Activities

2.1 Arizona Public Service Alternative Fuel Pilot Plant

The AVTA teamed with Electric Transportation Applications and Arizona Public Service (APS) to develop the APS Alternative Fuel Pilot Plant (Figure 1), which produces and compresses H2 on site. The H2 is produced through electrolysis, by operating a PEM fuel cell in reverse. The Pilot Plant also compresses natural gas on site. The Pilot Plant is used to fuel vehicles that operate on 100% H2 and blends of 15 to 50% H2 and compressed natural gas (HCNG).

The hydrogen subsystem process (Table 1 and Figure 2) includes hydrogen output at the fuel cell at 150 psi. The H2 is then dried (Figure 3) and stored at low pressure. The H2 is then compressed (Figure 4), filtered, and stored at 6,000 psi (Figure 5), where it is ready for use. The Pilot Plant also includes fuel dispensers and an electronic billing interface; it can dispense pure H2, pure CNG, or HCNG blends.

Figure 1. APS Alternative Fuel Pilot Plant and fueling pumps.

Table 1. Capabilities of the hydrogen subsystem components.

Hydrogen subsystem component	**Capacities**
Hydrogen Generator	PEM fuel cell, 57 kW, 20 cells 300 SCFH H2 17 kWh per 100 SCF H2
Hydrogen dryer	Lectrodryer, 300 SCFH, –80°F dew point
Compressor	Oil-free diaphragm, 3 phase, 5 ph, 480 V, 6,100-psi output
Low-pressure storage	8,955 SCF @ 150 psi
High-pressure storage	17,386 SCF @ 6,000 psi
Hydrogen purity	99.9997%

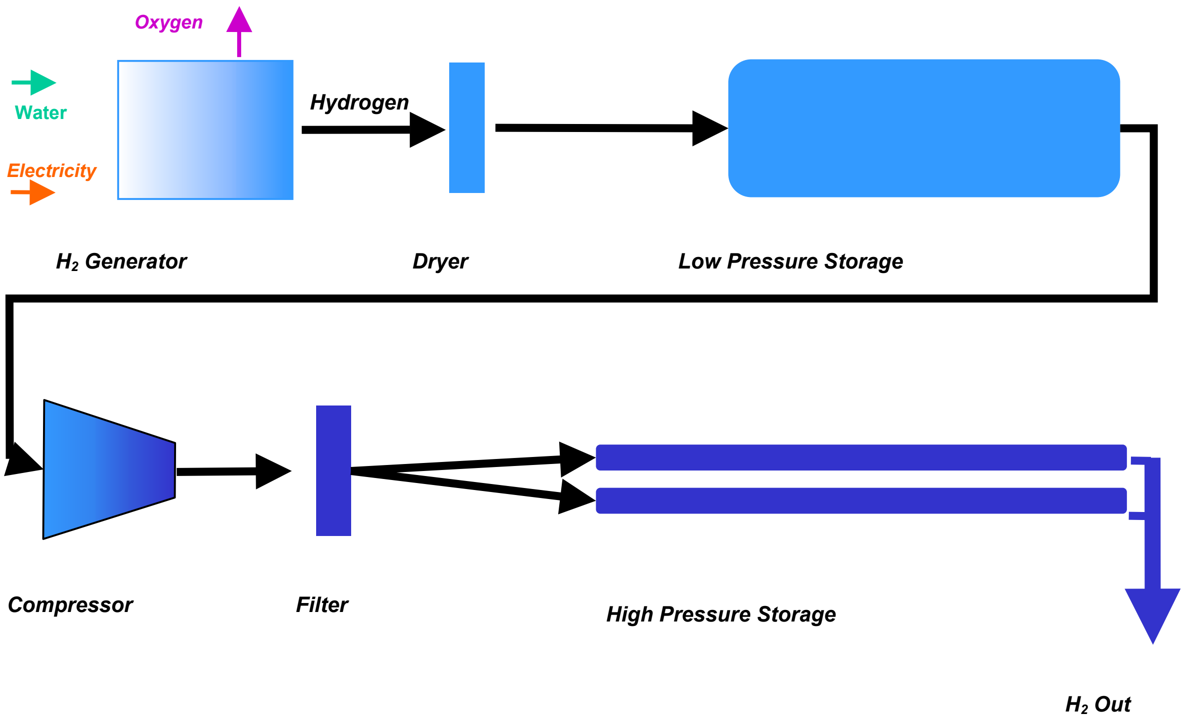

Figure 2. Arizona Public Service Alternative Fuel Pilot Plant hydrogen subsystem.

Figure 3. Hydrogen drier.

Figure 4. Hydrogen compressor.

Figure 5. Hydrogen low-pressure storage tank (large lower tank), high-pressure storage tanks (two narrow tanks on top), and PEM fuel cell (gray box on right).

2.2 Hydrogen Vehicle Testing

The H2 ICE test vehicles using the H2 and HCNG fuel produced by the Pilot Plant include:

- 100% H2 Mercedes Benz van
- Ford F-150 operating on up to 30% HCNG
- Ford F-150 operating on up to 50% HCNG
- Dodge van operating on 15% HCNG
- Eight APS meter reader vehicles (S-10 and Sierra pickups, and Blazers) operating on 15% HCNG
- A new Ford engine, operating on 100% H2, which is being mapped and installed in the Ford F-150 currently operating with the 50% HCNG engine
- An additional ten Phoenix Fire Department Ford pickups operating on 15% HCNG are beginning added. The Fire Department uses a different billing interface than the APS meter reader vehicles, so the Pilot Plant billing interface required upgrading.

The H2 ICE vehicle testing includes baseline performance, fleet, accelerated reliability testing, and emissions testing. To date, these test vehicles have accumulated 170,000 miles while fueled with H2 and HCNG.

2.2.1 F-150 50% HCNG Testing

The up-to-50%-blend HCNG test vehicle was a model year 2001 Ford F-150 gasoline vehicle modified to run on a blend of CNG and H2 by NRG Technologies, Inc., of Reno, Nevada. The modifications include:

- SVO heads
- Exhaust Intercooler
- Supercharger
- Exhaust gas recirculator
- Ignition modification
- Three Quantum hydrogen tanks.

The 50%-blend F-150 was converted by NRG Technologies to be a super-low-emission vehicle (SULEV). Because of its low emissions, its vehicle exhaust can be cleaner than the ambient air. The F-150 was operating on a 30% hydrogen blend at the time of emissions testing (Table 2). Arizona Public Service also randomly selected a Ford F-150 equipped with a factory gasoline engine and tested its emissions (Table 3).

Table 2. Federal Test Procedure 75 emissions test results for 50% F-150, operating on 30% HCNG blend at the time of testing (grams/mile).

Test Date	Mileage	NMHC	CH_4	HC	CO	NO_X	CO_2
10/24/2001	87	0.0014	0.108	0.123	0.879	0.005	518.1
NMHC = nonmethane hydrocarbons			CO = carbon monoxide			CH_4 = methane	
NOx = oxides of nitrogen.			HC = total hydrocarbons			CO_2 = carbon dioxide	

The results show a decrease in measured emission levels (excluding methane) compared to gasoline. Carbon monoxide emissions measured 0.879 gram per mile (g/mi), well under the 1 g/mile California SULEV standard, and the vehicle had virtually zero nitrogen oxide emissions. For a more complete discussion of the F-150 50% HCNG vehicle operations and testing, see the *High-Percentage Hydrogen/CNG Blend Ford F-150 Operating Summary* report.[1]

Table 3. Federal Test Procedure 75 emissions test results for a gasoline-fueled F-150 (grams/mile).

Test Date	Mileage	NMHC	CH_4	HC	CO	NO_X	CO_2
6/20/2001	23497	0.122	0.013	0.136	1.644	0.170	620.709
6/21/2001	23519	0.107	0.011	0.119	1.457	0.163	623.015
Average		0.114	0.012	0.127	1.551	0.166	621.862

2.2.2 F-150 30% HCNG Testing

The up-to-30%-blend HCNG test vehicle is a model year 2000 F-150, originally equipped with a factory CNG engine. It was also modified by NRG Technologies to run on a blend of CNG and 28% hydrogen (by volume). The modifications included adding a supercharger, making ignition modifications, and adding an exhaust gas recirculator. The vehicle uses the factory-installed carbon steel CNG fuel tank, which operates at 3600 psig.

Emissions from the 30% F-150 were measured using both the Inspection and Maintenance Driving Cycle (IM-240) and Federal Test Procedure 75 (FTP-75) test cycles (Table 4). The vehicle was tested several times to validate the results. Carbon monoxide emissions from the low-percentage-blend F-150 averaged 0.26 g/mi over the FTP-75 tests, well under the California SULEV standard of 1 g/mi. Nitrogen oxide emissions averaged 0.078 g/mi, near the California ULEV standard of 0.07.

Table 4. Emissions test results (grams/mile) for the 30% HCNG F-150.

Test Date	Mileage	NMHC	CH_4	HC	CO	NO_X	CO_2
FTP							
5/2/2001	1592	0.011	0.075	0.094	0.237	0.063	440.606
5/3/2001	1613	0.019	0.084	0.118	0.249	0.094	441.442
5/4/2001	1636	0.024	0.082	0.121	0.267	0.094	437.370
5/8/2001	1657	0.017	0.099	0.133	0.257	0.084	439.940
6/14/2001	2148	0.028	0.091	0.136	0.223	0.104	435.899
8/30/2001	3890	0.028	0.074	0.116	0.348	0.051	442.515
8/31/2001	3915	0.028	0.067	0.107	0.210	0.053	437.009
Average		0.022	0.081	0.117	0.255	0.077	439.254
IM240							
5/2/2001	1592	0.062	0.05	0.124	0.135	0.040	392.720
5/3/2001	1625	0.008	0.042	0.057	0.118	0.025	402.205
5/4/2001	1647	0.014	0.054	0.078	0.146	0.023	410.147
5/8/2001	1670	0.016	0.069	0.098	0.101	0.022	411.302
8/30/2001	3901	0.014	0.054	0.078	0.077	0.089	397.635
8/30/2001	3903	0.016	0.028	0.049	0.125	0.051	402.614
8/31/2001	3928	0.013	0.045	0.066	0.101	0.019	397.634
8/31/2001	3931	0.013	0.026	0.045	0.095	0.033	396.020
Average		0.019	0.046	0.074	0.112	0.037	401.285

Table 5 illustrates the emissions comparison between the HCNG 30% blend F-150 and the random-gasoline-fueled F-150. Reductions were achieved in all major emission categories. Carbon monoxide emissions from the 30% blend F-150 were impressive compared to the gasoline-fueled F-150 (83% reduction). Likewise, nitrogen oxides were reduced by more than half. Total hydrocarbon emissions showed a 7.5% drop, and carbon dioxide was cut by nearly 30%. For a more complete discussion of the F-150 50% HCNG vehicle operations and testing see the Low-*Percentage Hydrogen/CNG Blend Ford F-150 Operating Summary* report.[2]

Table 5. Percent reduction in emissions (HCNG versus gasoline-fueled F-150).

HC	CO	NO_X	CO_2
7.6%	83.5%	53.4%	29.4%

3. Hybrid Electric Vehicles

3.1 HEV Accelerated Reliability and Fleet Testing

The AVTA has three models of HEVs in fleet and accelerated reliability testing (160,000 miles per vehicle). The HEVs have accumulated almost 750,000 test miles as of July 2003. The number of test vehicles per model, the miles driven per HEV model, and the average miles per gallon fuel economy are shown in Table 6. On a monthly basis, the total average fuel economy for the four Honda Civic HEVs averaged between 34.5 and 42.1 mpg; the six Honda Insight HEVs averaged between 41.6 and 53.8 mpg; and the six Toyota Prius HEVs averaged between 36.5 and 51.3 mpg. Because the monthly mpg results for a single vehicle can be highly influenced if a fueling occurs right before or right after the end-of-month data collection cutoff, only the average results for all test vehicles are presented.

Fleet drivers in various routes are driving the vehicles throughout Arizona. The fleets driving the vehicles are:

- Bank One
- Red Cross
- Arizona Public Service
- ETA.

Table 6. Hybrid electric vehicle (HEV) test vehicle models, number of units per model in testing, average fuel economy [miles per gallon (mpg)], and EPA-estimated fuel economy.

HEV Model	Number of Units	Total Miles Driven (7/01/03)	Cumulative Average MPG	EPA Mileage Estimate City/Highway[3]
Honda Civic	4	196,000	38.8	47/48
Honda Insight	6	261,000	46.5	57/56
Toyota Prius	6	281,000	41.5	52/45

The vehicles are not exhibiting the same fuel economy as the EPA-tested mileage. When compared to the average EPA-estimated fuel economy (city + highway / 2), the Civic and Insight are both getting 82% of the estimated average; the Prius is getting 86% of the estimated average. This may be due to the nature of the applications the vehicles are used in. Generally, the fleet drivers are more concerned with accomplishing their tasks than maximizing mileage. However, given the number of test miles accumulated, the fuel economy results are likely to represent the results other fleets will encounter.

Examining the monthly average fuel economy for each HEV model (Figure 6) suggests a correlation between warm/hot weather during the summer months and lower fuel economy. This is evident for all three HEV models. Causes may include greater use of air conditioning in terms of time used, increased vehicle idling times in order to keep the air conditioning on, and the air conditioning turned to maximum levels. The likely cause is probably some combination of all three.

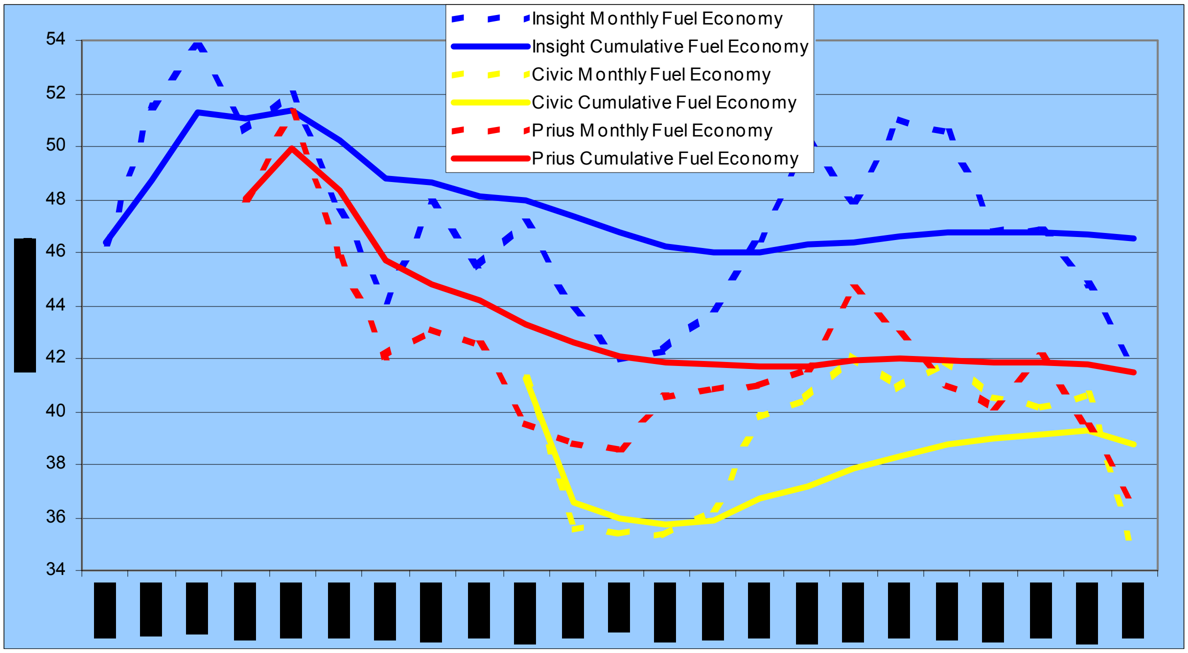

Figure 6. Cumulative and monthly average fuel economy (miles per gallon) values for six Honda Insight, four Honda Civic, and six Toyota Prius hybrid electric vehicles.

In addition to fuel use, other data being collected includes standard maintenance and repair records, as well as any abnormalities unique to HEVs. The results will be reported for each vehicle and each group of the same vehicle models as the vehicles complete testing. The data will be available at http://avt.inel.gov/hev.html, the vehicles have performed well, though the original equipment tires seem to require replacement either from wear or failure at relatively low mileage, and replacement original equipment tires are not always available.

3.2 Hybrid Electric Vehicle Baseline Performance Testing

The baseline performance HEV test parameters include acceleration, gradeability, handling, maximum speed, and braking testing, as well as two fuel economy tests. Both fuel economy tests are conducted identically (SAE J1634), with the exception that one is conducted with the air conditioning off, the other with the air conditioning on maximum.[4] To date, the Civic, Insight, and Prius HEVs have all undergone baseline performance testing.

The drive cycle fuel economy testing results with the air conditioning off compared to the air-conditioning-on-maximum testing averaged 12.1 mpg higher for the three HEVs. The Insight had the highest delta, with 13.5 higher mpg with the air conditioning off than on maximum (Figure 7).

Compared to the EPA fuel economy results, only the drive cycle testing with the air conditioning off resulted in mpg values near the EPA results. It is interesting that the fuel economy as measured for each HEV model during the 750,000 miles of fleet and accelerated reliability testing (yellow bars) was between the dynamometer drive cycle test results for the air-conditioning-on-maximum tests (blue bars) and drive cycle test results with air the conditioning off (red bars), which suggests that the two SAE J1634 tests are accurate measures of real-world fuel economy experienced during HEV fleet operations.

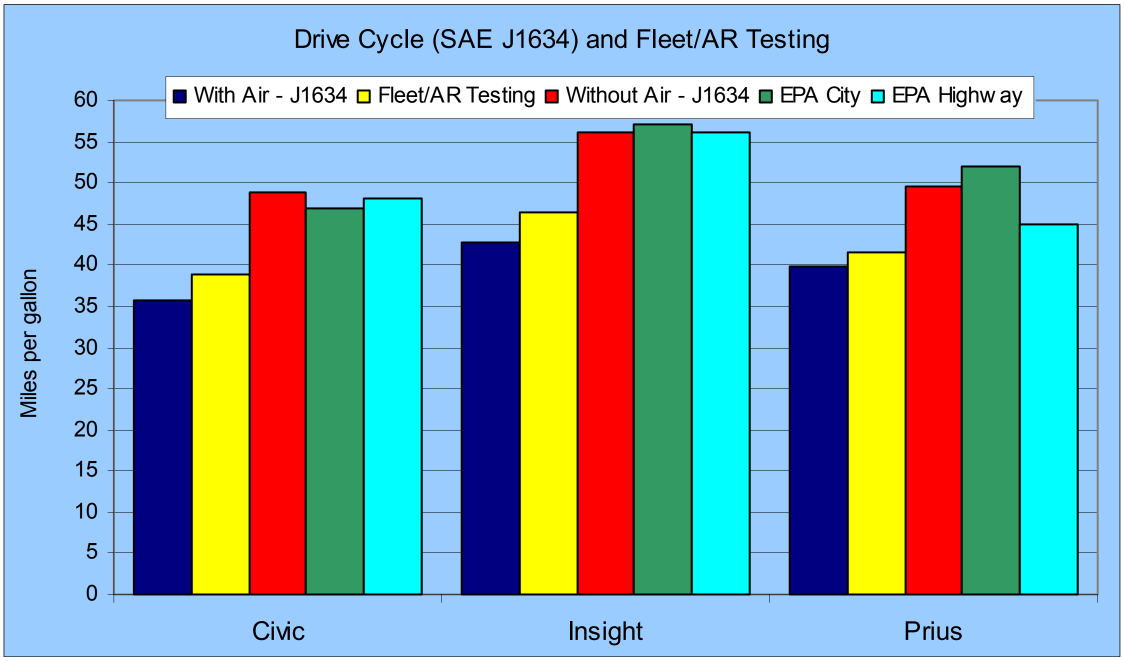

Figure 7. Honda Civic, Honda Insight, and Toyota Prius HEV fuel economy measurements, including SAE J1634 with air-conditioning-on-maximum (dark blue bar), fleet operations and accelerated reliability testing (yellow bar), and SAE J1634 testing with the air conditioning off (red bar) compared to the EPA city (green bar) and highway (light blue/aqua bar) estimated fuel economies.

4. Neighborhood Electric Vehicles

Neighborhood electric vehicles (NEVs), which have top speeds of 20 to 25 miles per hour and are legal in about 40 states on roads generally up 35 miles per hour, are increasingly being used in many applications, ranging from National Parks such as Yellowstone and Yosemite, to military reservations such as Luke Air Force Base (with over 400 NEVs), and to retirement and planned communities. Given the relatively low manufacturing infrastructure investment requirements, the barriers to entering the NEV manufacturer market have resulted in several new NEV products being announced, though never being manufactured in any number. In addition, NEV customers are often experiencing battery propulsion for the first time, and they may be unaware of such issues as battery watering needs for lead acid batteries, the tradeoffs between power and energy use, or charging methodologies and requirements. In order to educate potential NEV users, sustain the growth of a quality NEV market, and support wise financial investments by Federal Fleets, the AVTA initiated baseline performance testing of ten NEVs and published the results (Table 7).

The NEV baseline performance testing[5] test parameters include acceleration, gradeability, handling, maximum speed, maximum range, braking, charger efficiency, charging time, and compliance with Federal Motor Vehicle Safety Standard No. 500. The ten NEV models baseline performance tested had an overall average range of 37.8 miles per charge, varying from 30.9 to 52.9 miles (Figure 8).

Table 7. Neighborhood electric vehicles baseline performance tested to date, vehicle style, and manufacturing status.

Manufacturer	Style	Manufacturing Status
Ford/TH!NK	2 passenger	Inactive
	4 passenger	Inactive
Frazier Nash	4 passenger	Inactive
	2 passenger pickup bed	Inactive
Global Electric Motors (GEM)	2 passenger	Active
	4 passenger	Active
	2 passenger short flat bed	Active
	2 passenger long flat bed	Active
ParCar	2 passenger	Active
	4 passenger	Active

Charging time for the two TH!NK *city* NEVs was 8.3 hours, for the four GEMS it was 9.4 hours, and for the two ParCars it was 11.3 hours. These vehicles were all charged at Level I (115 to 120 VAC). The two Frazer-Nash NEVs were fast charged (Level III), each taking almost an hour to charge, which exceeds the performance goal of 30 minutes for fast charging.

The AVTA is also currently testing approximately 75 NEVs in fleet testing (including some fast charged) in the cities of Palm Valley and Palm Springs, as well as at Luke Air Force base. (The results will be reported at a later date.)

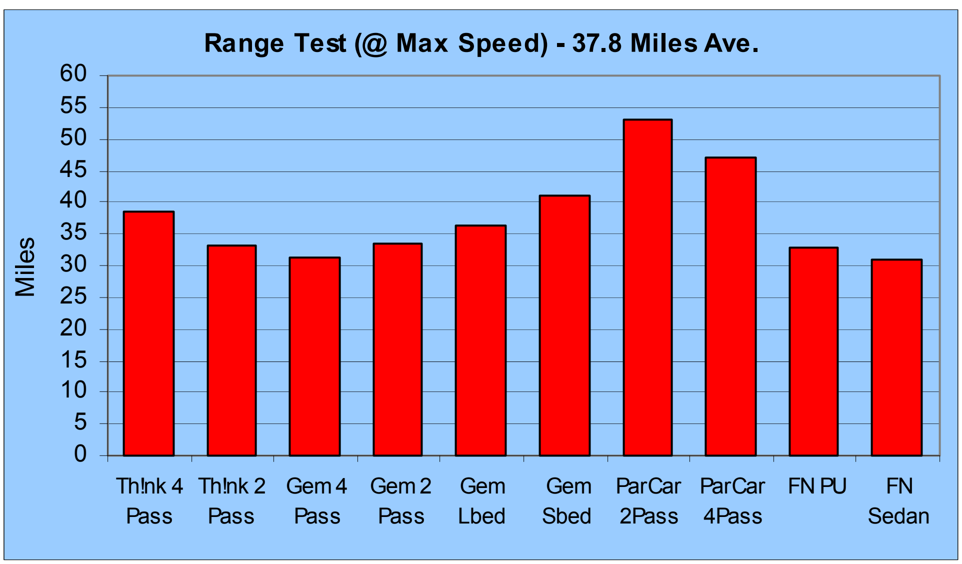

Figure 8. Range testing results during NEV baseline performance testing conducted at maximum speed. (Pass = passenger, Lbed = long bed, Sbed = short bed, FN = Frazier Nash, PU = pickup).

5. Urban Electric Vehicles

In partnership with the New York Power Authority, the AVTA has 87 TH!NK *city* UEVs in a commuter fleet demonstration in New York City suburbs. In partnership with Ford, another 240 *city* UEVs are in a national demonstration program.

5.1. New York Commuter Fleet Demonstration

Suburban New York City railroad commuters use TH!NK *city* UEVs to commute from their private residences to railroad stations outside of New York City where they catch commuter trains into New York City. Electric vehicle charging infrastructure for the TH!NK *city* UEVs is located at each commuters' private residence as well as at seven train stations. Eighty-seven commuters are currently using the TH!NK *city* vehicles, with 80% actively providing data to the AVTA. As of July 2003, the participants have driven the vehicles 216,000 miles since Program inception, avoiding use of almost 9,000 gallons of gasoline. The TH!NK *city* vehicles are driven an average of between 180 and 230 miles per month, and over 95% of all trips taken with the TH!NK *city* vehicles replace trips previously taken in gasoline vehicles (Figure 9). Other information being collected in the New York commuter demonstration program (via an internet-based questionnaire) includes driver demographics (age, income, other household vehicles, etc.), vehicle acceptance and vehicle use. Additional information can be obtained by accessing the NYPA/TH!NK Clean Commute Program Report.[6]

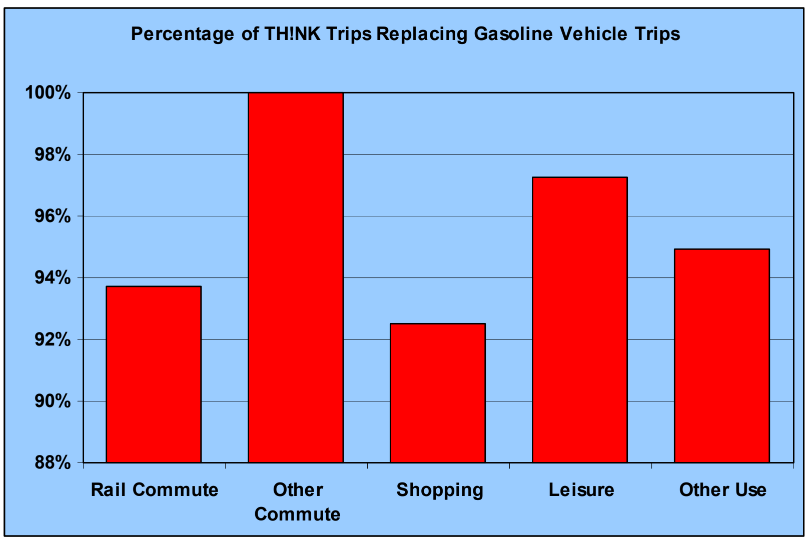

Figure 9. Gasoline vehicle trips replaced by commuters using TH!NK *city* UEVs.

5.2. Ford/AVTA National Demonstration Program

The Ford/AVTA Demonstration Program[7] is the largest UEV demonstration program in the United States. The goals of the Program include:

- Enhancing public awareness of UEVs
- Defining the unique UEV market and niche applications
- Enhancing EV infrastructure
- Investigating economic sustainability of UEVs.

Through the Ford/AVTA National Demonstration Program, 240 TH!NK *city* UEVs have been placed in California (185), Georgia (15), and Michigan (40). This activity is ongoing, and the activities will be reported annually, with the first annual report (*TH!NK city Electric Vehicle Demonstration Program*) available on the WWW at: http://avt.inel.gov/uev/ThinkcityDemoReport.pdf

5.3. UEV Baseline Performance Testing

A TH!NK *city* has also completed UEV baseline performance testing, which includes three range tests per charge. The results were 30.2 miles during the SAE J1634 test, 65.5 miles at a constant test speed of 35 mph, and 40.5 miles at the maximum vehicle speed (54 mph). The *city* required 7.15 hours to charge; it had a charging efficiency of 2.2 miles per kWh; and during the 35-mph constant speed test, its energy efficiency was 7.4 miles per kWh.[8]

6. Ground Support Equipment

The AVTA is developing baseline performance test specifications and test procedures for airport electric ground support equipment (GSE) for three classes of GSE vehicles: airplane pushback tractors, baggage tugs, and airplane belt loaders. The specifications and procedures will be drafted and presented to industry for input and comment. After the testing specifications and procedures are finalized, the AVTA will initiate testing of several pieces of electric GSE to quantify performance and petroleum reduction capabilities.

7. Summary

Hydrogen ICE Vehicles. In addition to supporting the overall goal of the Department of Energy and the AVTA to reduce petroleum consumption, demonstrating emissions reductions makes acceptance of 100% hydrogen (H2) as a transportation fuel more likely in internal combustion engine vehicles, either in pure form or blended with compressed natural gas (CNG). All of the HCNG vehicles have operated very well, with the 30 and 50% HCNG vehicles yielding exceptional emissions results. In addition, preliminary testing indicates it may be possible to extend oil change intervals well beyond the conventional 3,000 miles by using HCNG fuel, thus lowering operating costs, decreasing waste products, and again reducing petroleum consumption. The AVTA will continue to investigate the H2 internal combustion engine vehicle possibilities and the operational enhancements possible to the H2 Pilot Plant.

Hybrid Electric Vehicles. While the hybrid electric test vehicles in fleet applications have not achieved the advertised fuel economy results, they do exhibit very high fuel efficiencies. There have been no propulsion battery failures, thus avoiding battery replacement costs of over $5,000 per vehicle. As the vehicles complete testing, they are being sold by the same method consumers use—the newspaper car-for-sale advertisement pages. This is allowing calculation (and eventually publication) of accurate life-cycle costs, including the costs of maintenance, operations, miscellaneous repairs (a bicyclist rode into one vehicle, damaging the vehicle), purchase, and disposal. These costs can then be used by fleet managers to determine the point where increased gasoline costs are greater than any HEV incremental costs.

Neighborhood Electric Vehicles. The NEVs are continuing to be placed in applications where they yield both petroleum reduction and economic advantage. Unlike full-size electric vehicles, the NEVs have very low purchase and maintenance costs, making them very attractive alternatives to gasoline-powered vehicles in appropriate applications. The AVTA will continue testing NEVs as new products are introduced.

Urban Electric Vehicles. Though Ford/TH!NK has discontinued the *city* UEV, testing and evaluation continues, as the vehicle is being used to evaluate the concept of UEVs and station cars. Initial results suggest drivers are very receptive to using UEVs. The TH!NK *city* UEVs are being highly used; their top speed and range capabilities appear to be very acceptable for the urban environment they are being used in.

Ground Support Equipment. The GSE sector, while undergoing a difficult economic period, is under pressure to minimize emissions and fueling requirements. The GSE industry has showcased new products that use electric propulsion technologies, including pure electric and hybrid electric operating systems. The AVTA is developing the testing methods to support development of these emerging technologies.

8. References

[1] D. Karner and J.E. Francfort. *High-Percentage Hydrogen/CNG Blend Ford F-150 Operating Summary*. EXT 03-00007. Idaho National Engineering and Environmental Laboratory. Idaho Falls, ID. 2003.

[2] D. Karner and J.E. Francfort. *Low-Percentage Hydrogen/CNG Blend Ford F-150 Operating Summary*. EXT 03-00008. Idaho National Engineering and Environmental Laboratory. Idaho Falls, ID. 2003.

[3] U.S. Environmental Protection Agency. *Fuel Economy Guide*. www.fueleconomy.gov. 2003

[4] Electric Transportation Applications. *ETA-HTP003 Implementation of SAE J1634 May 93 – "Hybrid Electric Vehicle Energy Consumption and Ranged Test Procedure.*" http://avt.inel.gov/hev/hev_pdf/HTP003RA.PDF. 2001

[5] NEV baseline performance testing reports can be accessed at http://avt.inel.gov/nev.html.

[6] D. Karner and J.E. Francfort*. NYPA/TH!NK Clean Commute Program Report – Inception Through February 2003.* EXT 03-00846. Idaho National Engineering and Environmental Laboratory. Idaho Falls, ID. 2003. http://avt.inel.gov/uev/pdf/nypa2003annualreport.pdf.

[7] J.E. Francfort. *TH!NK city Electric Vehicle Demonstration Program*. INEEL EXT 02-01297. Idaho National Engineering and Environmental Laboratory. Idaho Falls, ID. 2002. http://avt.inel.gov/uev/ThinkcityDemoReport.pdf

[8] Electric Transportation Applications. *UEVAmerica 1999 Ford TH!NK city Urban Electric Vehicle* testing fact sheet. 2002. http://avt.inel.gov/uev/pdf/thinkcityueva.pdf

9. Author

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